1.11 Power Systems Development Facility: Operation of a Transport Reactor System With a Westinghouse Candle Filter

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Abstract

One of the most cost-competitive, coal-based power plant technologies is believed to be an air-blown, combined cycle incorporating a partial gasifier and pressurized char combustor. These two coal-conversion stages provide fuel gas and vitiated air to fire a combustion turbine. To protect the turbine from particle erosion damage, all the dust must be removed from the two hot gas streams. This operation involves high-temperature, high-pressure (HTHP) filtration, a technology currently under development at several locations funded by the Department of Energy. One of these locations is the Power Systems Development Facility* (PSDF) at Wilsonville, Alabama. The Power Systems Development Facility (PSDF) is an engineering scale demonstration of two potential air-blown, coal-based combined cycle power plant technologies with high-temperature, high-pressure gas filtration systems. The PSDF was designed at sufficient scale so that advanced power systems and components could be tested in an integrated fashion to provide data for commercial scale-up. This paper provides a process description and an operations summary of the M.W. Kellogg Transport reactor train located at the PSDF. The ongoing engineering and economic evaluation of the technologies under development at the PSDF and the status of the Foster Wheeler APFBC will be briefly discussed.

The Transport reactor is an advanced circulating fluidized bed reactor designed to operate as either a combustor or a gasifier. Hot gas particulate cleanup is achieved by using one of two filter systems (PCDs), located downstream of the Transport reactor. The Transport reactor has operated on coal as a combustor for over 2700 hours at pressures up to 220 psig and achieved over 3900 hours of solids circulation. Higher than expected coal feed rates and solid circulation rates corresponding to the operating pressure have been achieved. Initial problems associated with the startup burner and solids flow through the cyclone dipleg have been resolved. Although there were a number of operational problems with the dry coal feed system and ash removal systems early on, these systems operated much more reliably during the last test run.

Power Systems Development Facility: Operations of the M.W. Kellogg Transport Reactor with Westinghouse Candle Filter

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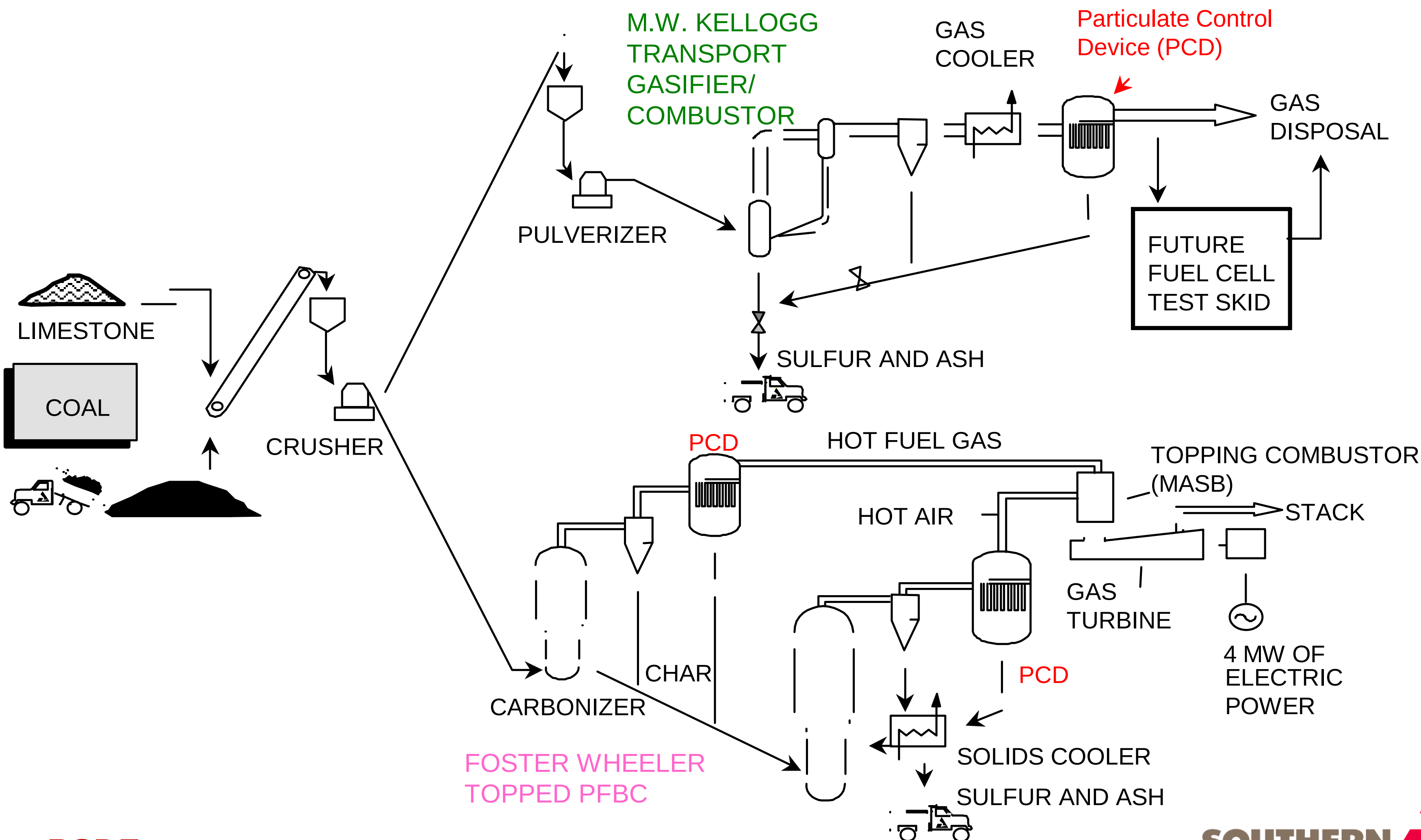
PSDF Simplified Flow Diagram



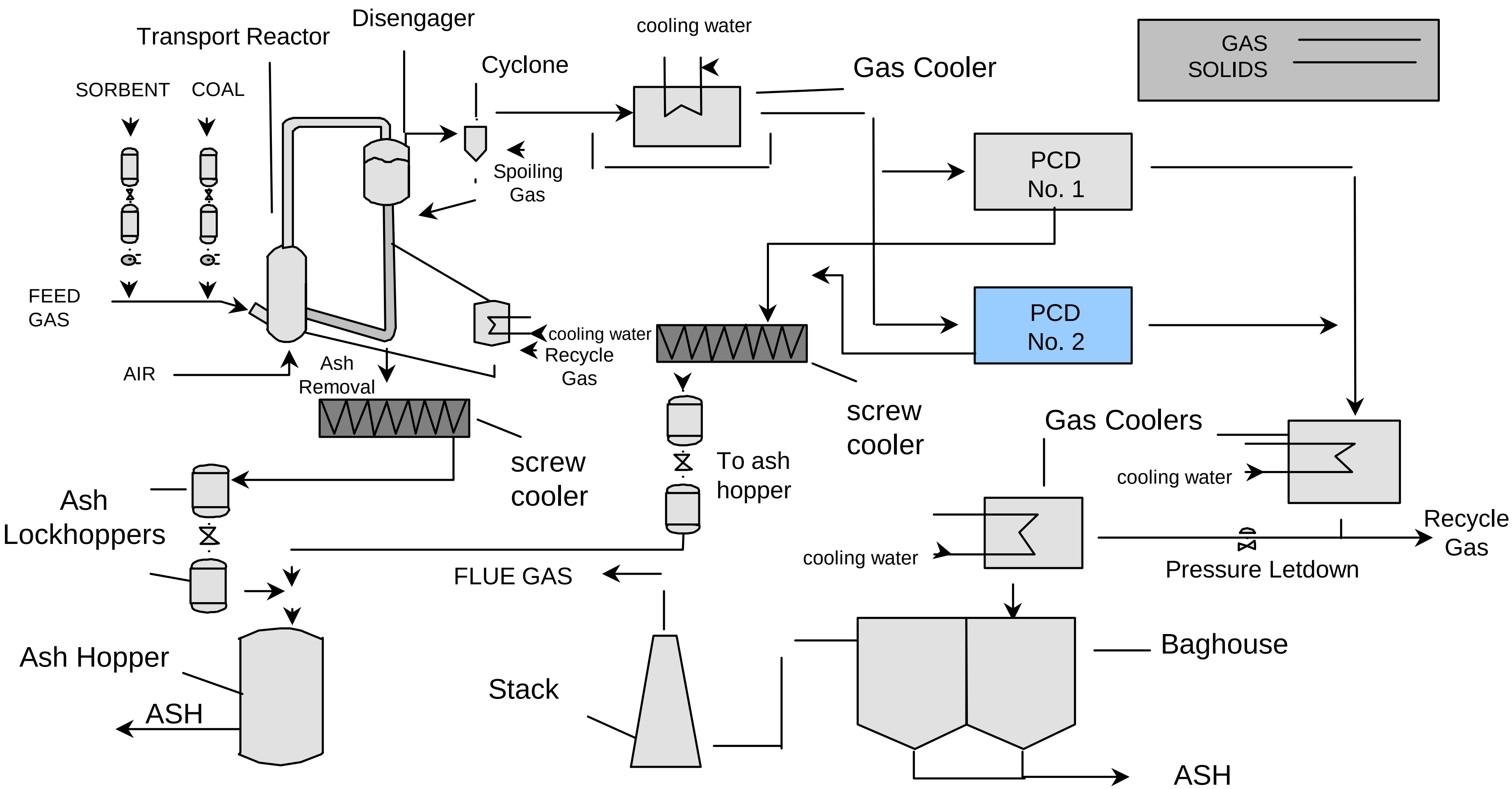
PSDF

Power Systems Development Facility

Status of Foster Wheeler Advanced PFBC Train

- Construction completed in March
  - all equipment blown down and and pressured tested
  - instrument loop checks complete
- Functional checks and cold shakedown in progress
- MASB to be fired mid August
  - if successful coal fire by mid September

Transport Reactor Train Process Flow Diagram Combustion Mode



PSDF

Power Systems Development Facility

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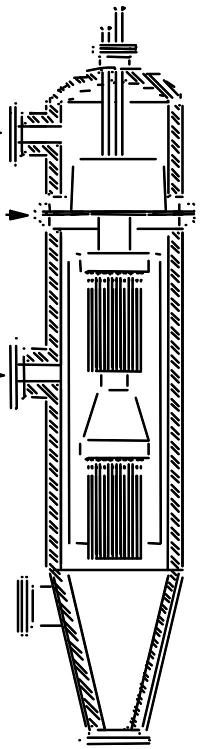
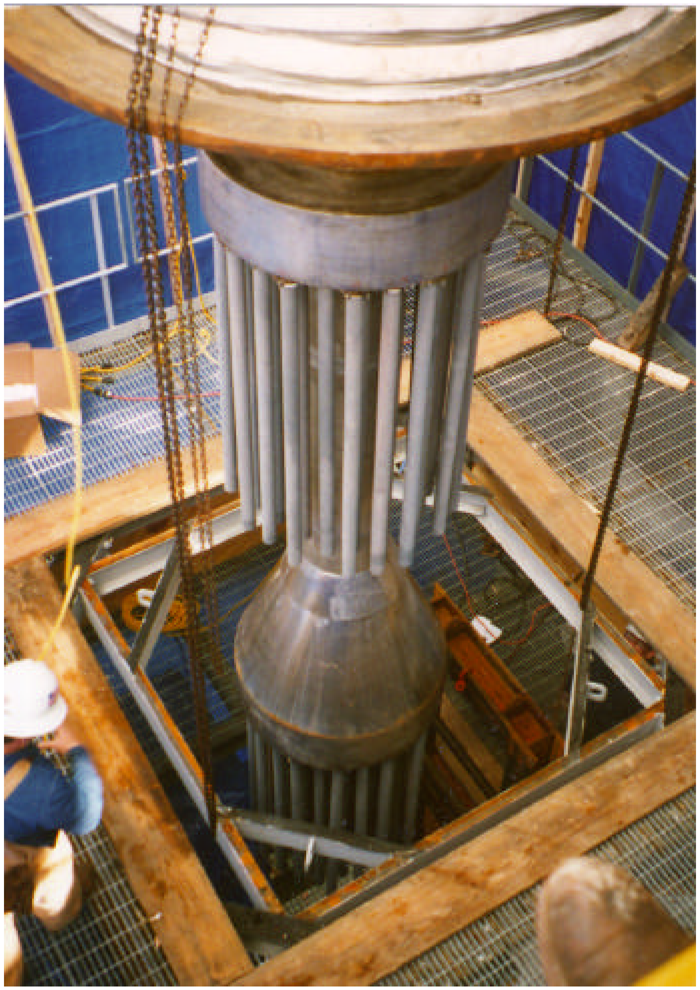
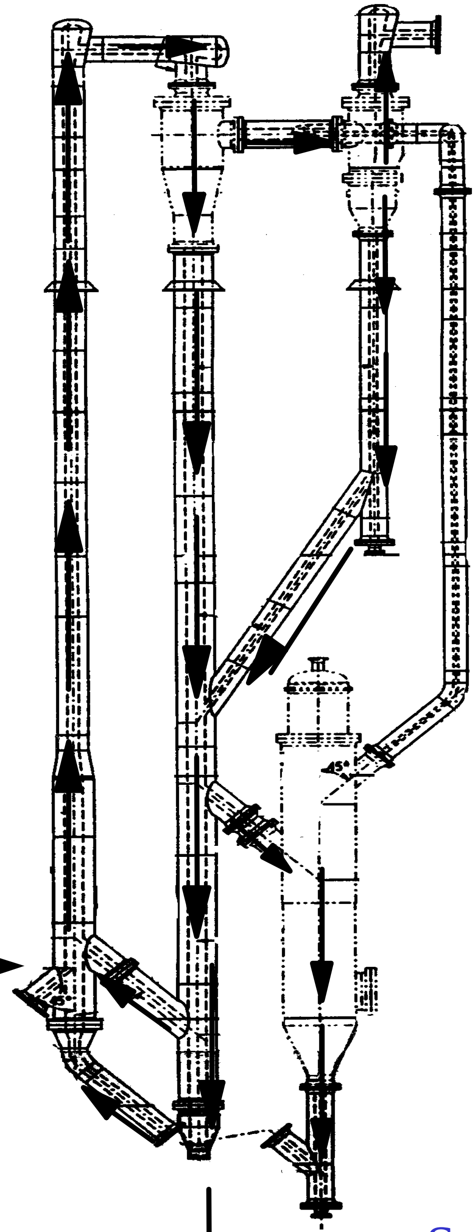
Westinghouse Filter System





Transport Reactor



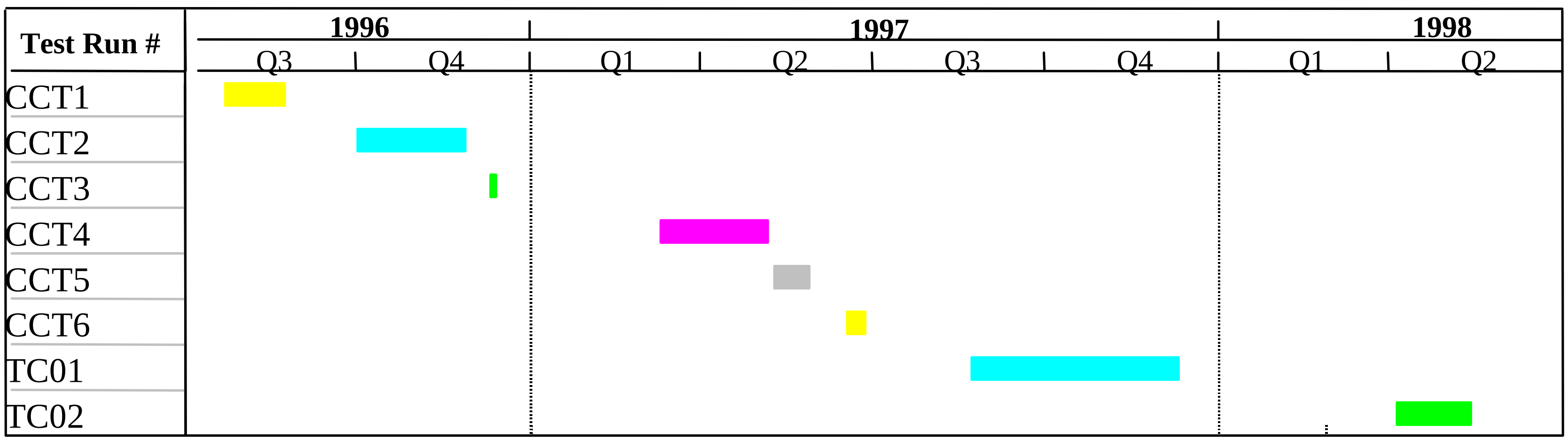
Process Gas

Coal
Sorbent
Air

Spent Solids

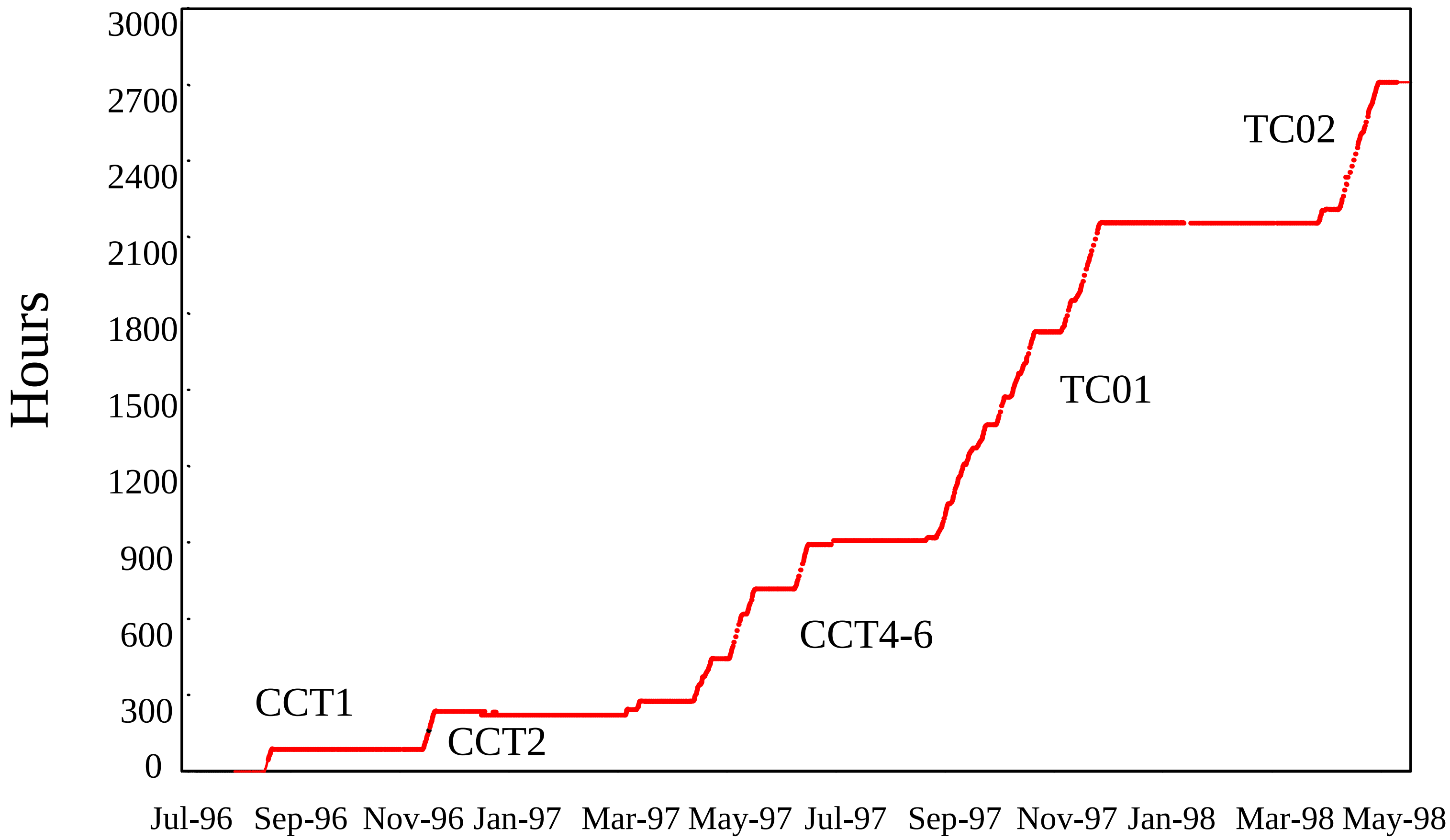
- Excellent gas-solids contact
- Low mass transfer resistance between gas and solids
- Highly turbulent atmosphere
- High coal throughput
- High heat release rate
- Designed without expansion joints

Transport Reactor Train Summary of Operations



Transport Reactor Train
Cumulative Hours on Coal

Through 5/14/98



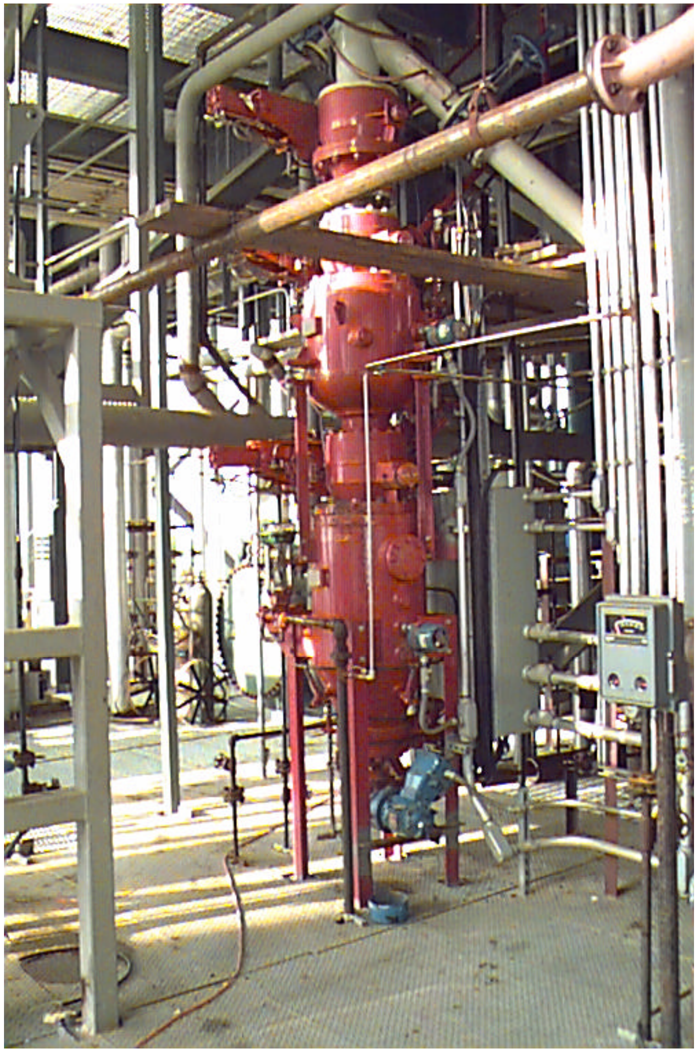
Transport Reactor Train Availability
(based on hours of coal feed)

TC01

- Process 55 %
- Reactor 97%

TC02

- Process 69 %
- Reactor 98%



Operating Conditions

- Coal = Calumet Mine Bituminous
  Mary Lee Seam in Alabama
- Sorbent Type = Plum Run Dolomite
- Reactor Temperature = 1575-1625 deg F
- Reactor Pressure = 160-220 psig
- Riser Velocity = 30-40 ft/s
- Excess Air = 15-35%
- Coal Feed Rate = 400-1500 lb/hr
- Coal Feed Mean Mass Diameter = 200-250 microns
- Dolomite Feed Mean Mass Diameter = ~ 250 microns

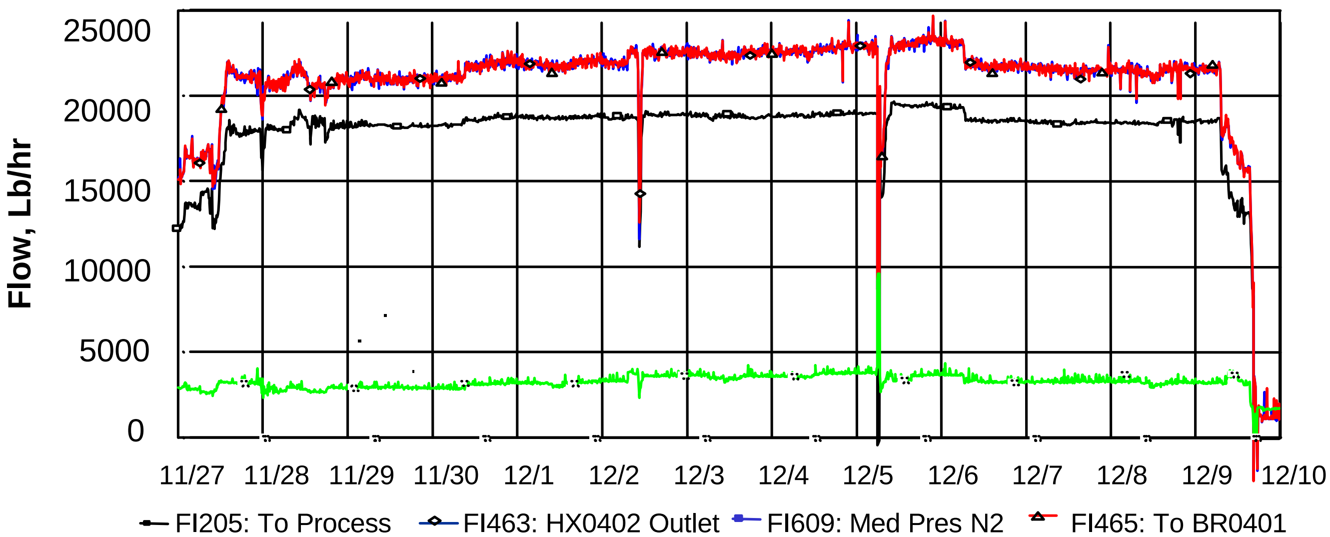
Alabama Coal

Moisture	3.4
Ash	16.2
Sulfur	0.9
C	67.7
H	4.5
N	1.6
O	5.7
Vol	30.1
Fix C	50.3

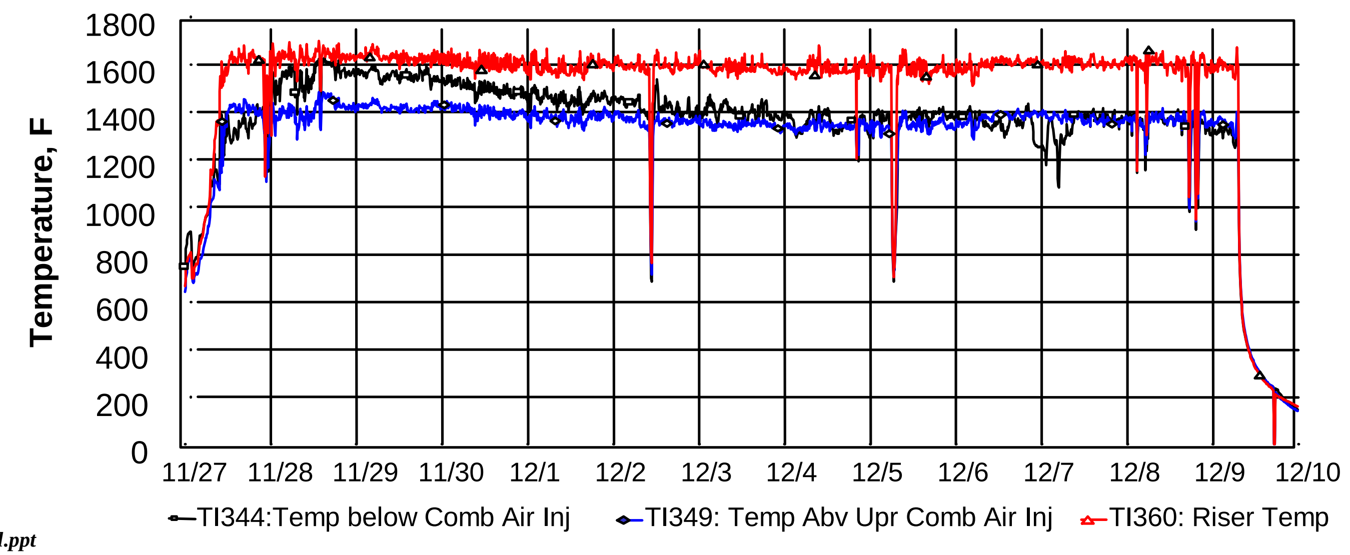
Plum Run
Dolomite Analysis

$CaCO_3$	52.3
MgCO3	44.1
Inerts	3.6

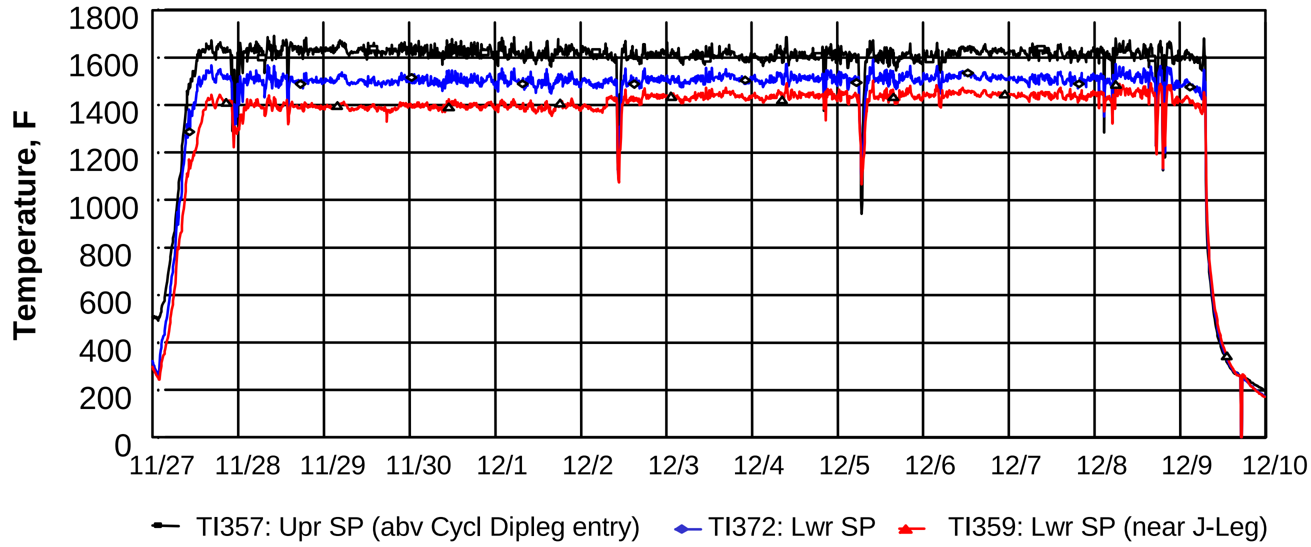
Total Gas In/Out Flowrates



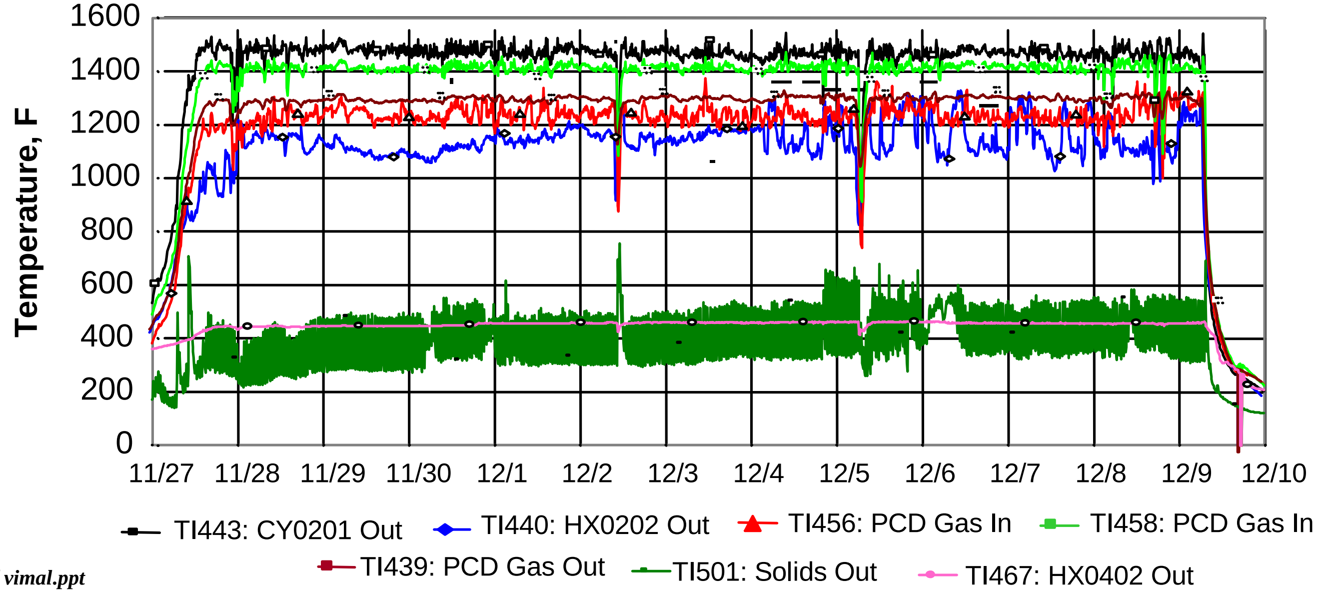
Reactor Mixing Zone & Riser Temperatures



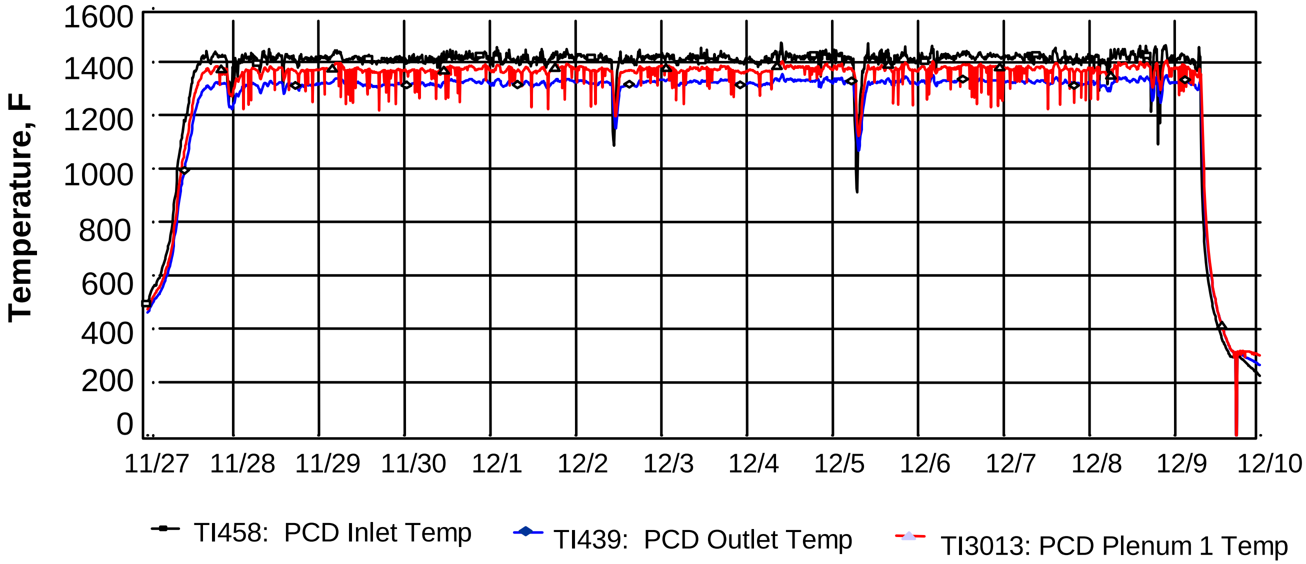
Standpipe Temperatures



Temperature Profiles Downstream of Reactor



PCD Temperatures



Transport Reactor: Observations and Achievements

- High carbon conversions (99.9+%) were achieved.
- Reactor operations were smooth with high heat release rates in the riser.
- A high solid circulation rate was established. With higher solid circulation the temperature difference between the riser and standpipe was low.
- Essentially complete carbon conversion and nearly complete sulfur capture occurs in the first pass due to highly effective gas-solid mixing and contacting.
- A turndown ratio of 4:1 on coal feed was achieved.

Transport Reactor: Observations and Achievements (cont)

- The disengager - cyclone design adopted facilitates the feeding of a larger particle size to the PCD which improves its operation.
- Successful cyclone dipleg operating concepts were developed, backed by theoretical understanding.
- The effect of PCD backpulse on transport reactor operations is manageable. Due to sizing of the facility, this is not an issue on commercial scale reactor.
- Solid circulation through the reactor and combustor heat exchanger can be independently controlled.

Transport Reactor: Observations and Achievements (cont)

- The concept of removing heat released in the riser and the control of reactor temperature during normal operation and turndowns was demonstrated using a closely integrated fluidized bed heat exchanger.
- Even with high heat release rates in the riser, excellent heat transfer and heat rejection rates were achieved.
- The external combustion heat exchanger design concept is feasible and attractive.
- Excellent heat removal rates in the combustor heat exchanger were achieved by varying the solids circulation rate through the heat exchanger.

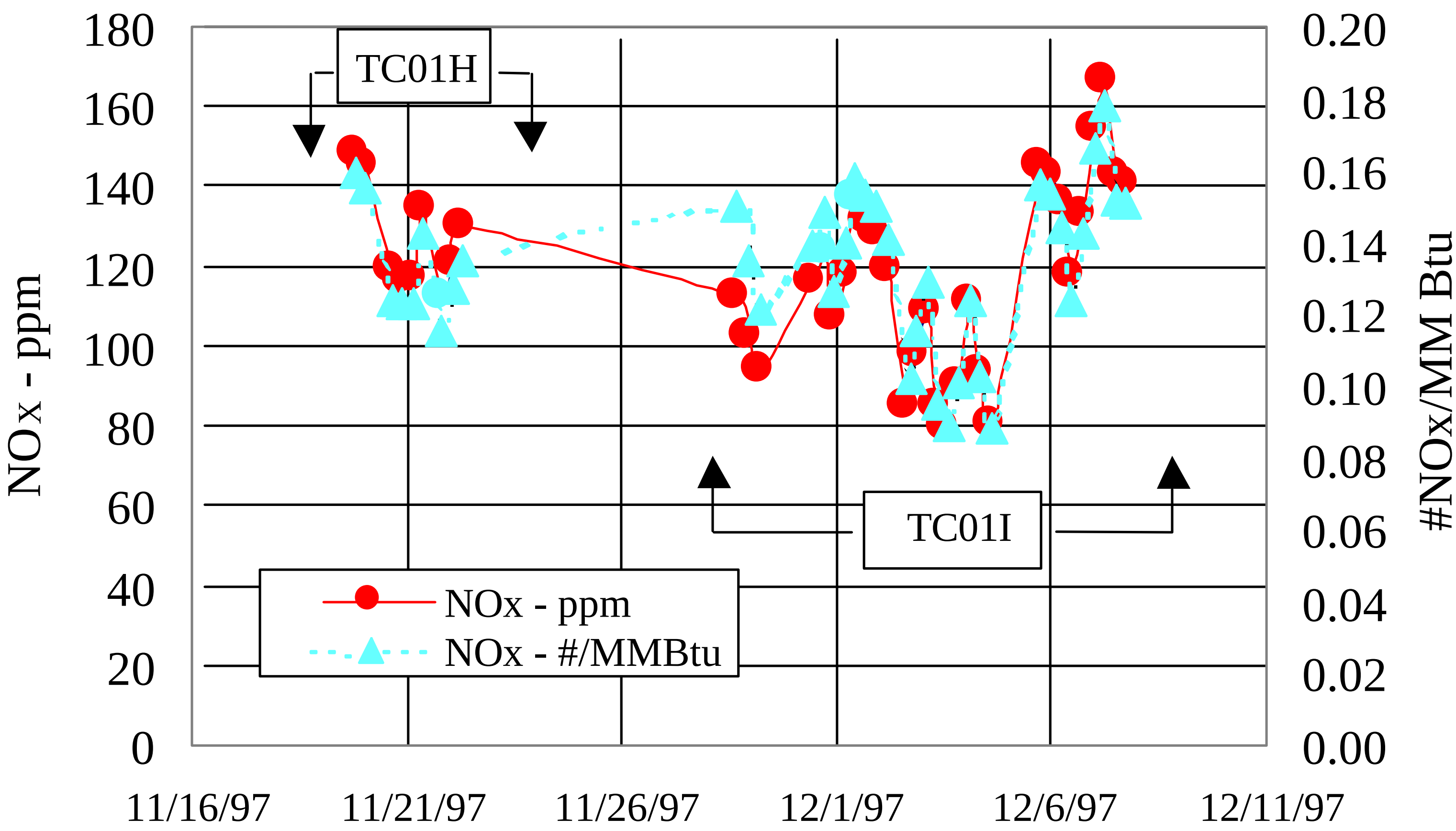
Transport Reactor: Observations and Achievements (cont)

- Startup burner firing rate was increased from 3.6 to 7.5 Mbtu/hr which resulted in higher reactor and PCD temperatures before starting coal feed.
- Various problems with the coal feed and ash removal systems were addressed. About 75% of outages were caused by these systems. Reliability of these systems was improved significantly in the last two test runs.
- Little refractory erosion was seen in more than 3950 hours of solid circulation. A good expanding cap design on riser top minimized the crossover refractory erosion. The heat transfer tubes in the combustor heat exchanger are still in pristine condition.

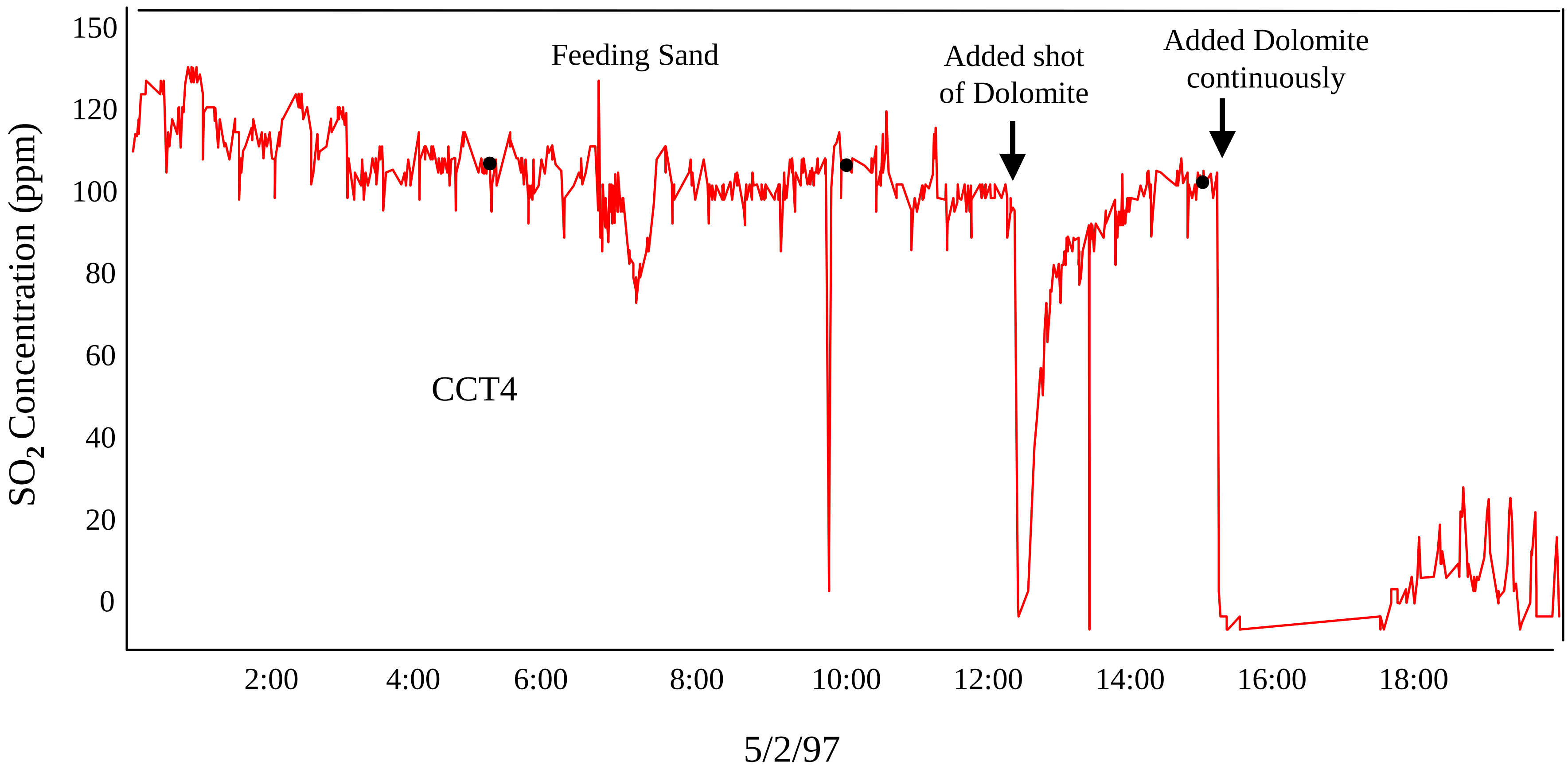
Transport Reactor: Observations and Achievements (cont)

- A viable mechanical design of reactor configuration was developed with no expansion joints.
- First-of-a-kind process flow sheet, piping and instrumentation diagrams (P&IDs), equipment designs, detailed mechanical, civil, electrical and control engineering designs, operations and control philosophy, and operating procedures are complete. They will be updated as more experience is gained with different fuels and sorbents.
- With the experience gained, significant improvements were identified that can be used for scaleup.
- Completed scheduled tests within reasonable time period due to stable reactor operations.

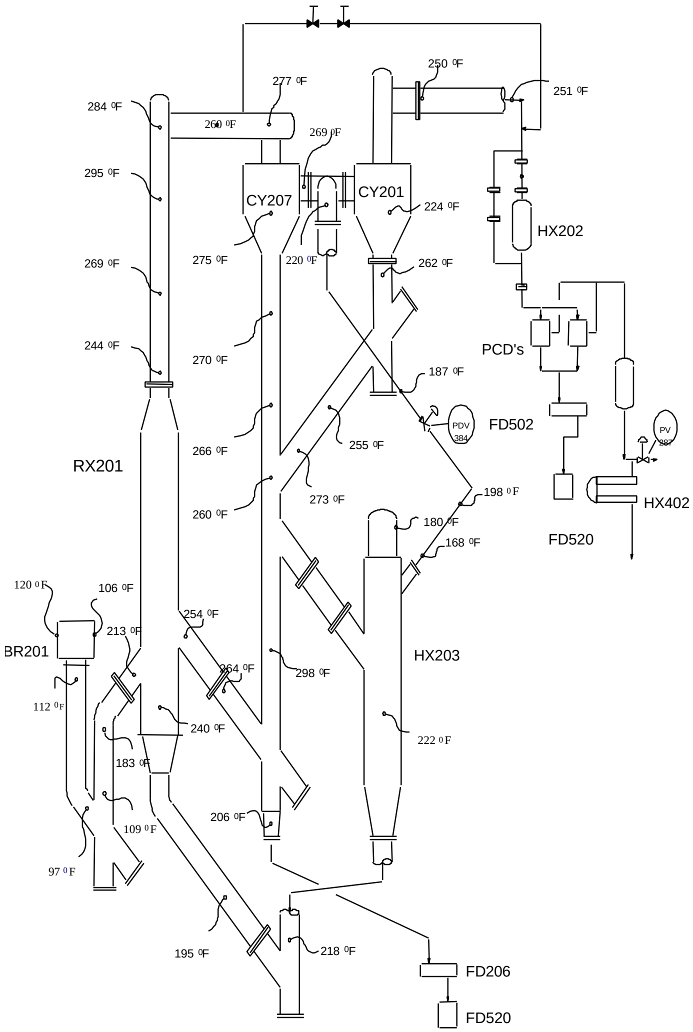
NO_X Emissions

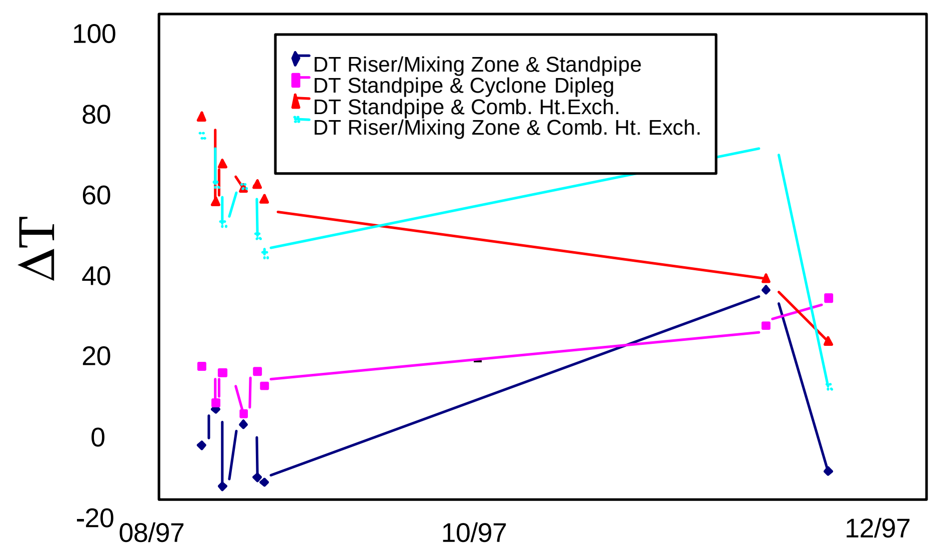


Effect of Dolomite Addition on SO_2 Concentrations



Skin Temperatures in Reactor Loop





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Test Schedule

- ***TC03*** - 500 Hour Combustion Run - Jun-July 1998
- ***TC04*** - 500 Hour Combustion Run - July-Aug 1998
- Sulfator Commissioning - Aug-Sept 1998
- ***TC05*** - 500 Hour Combustion Run - Nov-Dec 1998
- ***TC06*** - 500 Hour Combustion Run - Feb-Mar 1999
- Gasification process configuration changes -
  April-June 1999
- ***GCT1*** - Gasification commissioning - July-Sept 1999
- ***TC07*** - 500 Hour Gasification Run - Nov-Dec 1999